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(54) Abstract Title
OUTPUT POWER STABILIZATION OF WDM OPTICAL FIBRE AMPLIFIER

(57) An apparatus and method stabilises the output power of a WDM optical fibre amplifier according to the number of data channels. The output stabilising method comprises extracting part of an optical signal and WDM-demultiplexed the optical signal into light in the wavelength bands of data channels. The number of channels in use for the current transmission is detected by analysing the light in each wavelength band, and the intensity of the output optical signal is controlled according to the detected channel number. The apparatus may include a channel number detector 30, which comprises a demultiplexer (32), (which may be an arrayed - waveguide grating), an opto-electric converter (34), a comparator (36) and a shift register (38).

FIG. 2

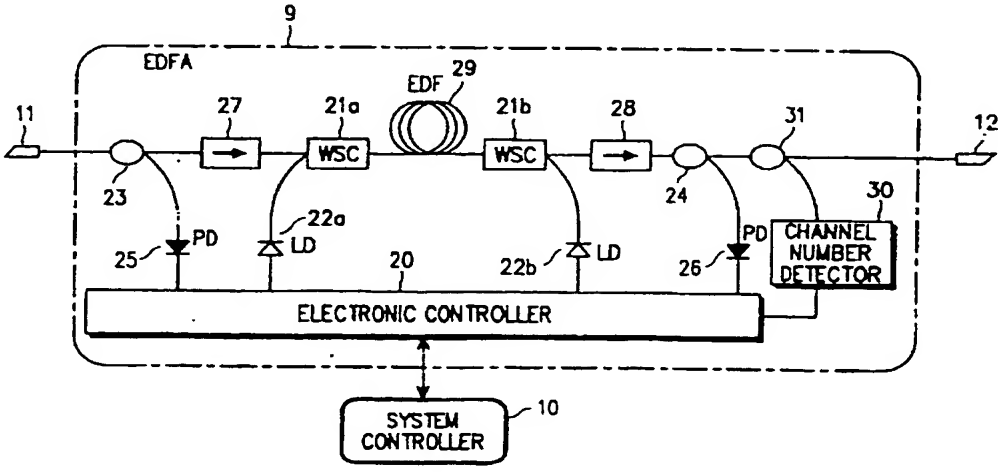

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FIG. 1

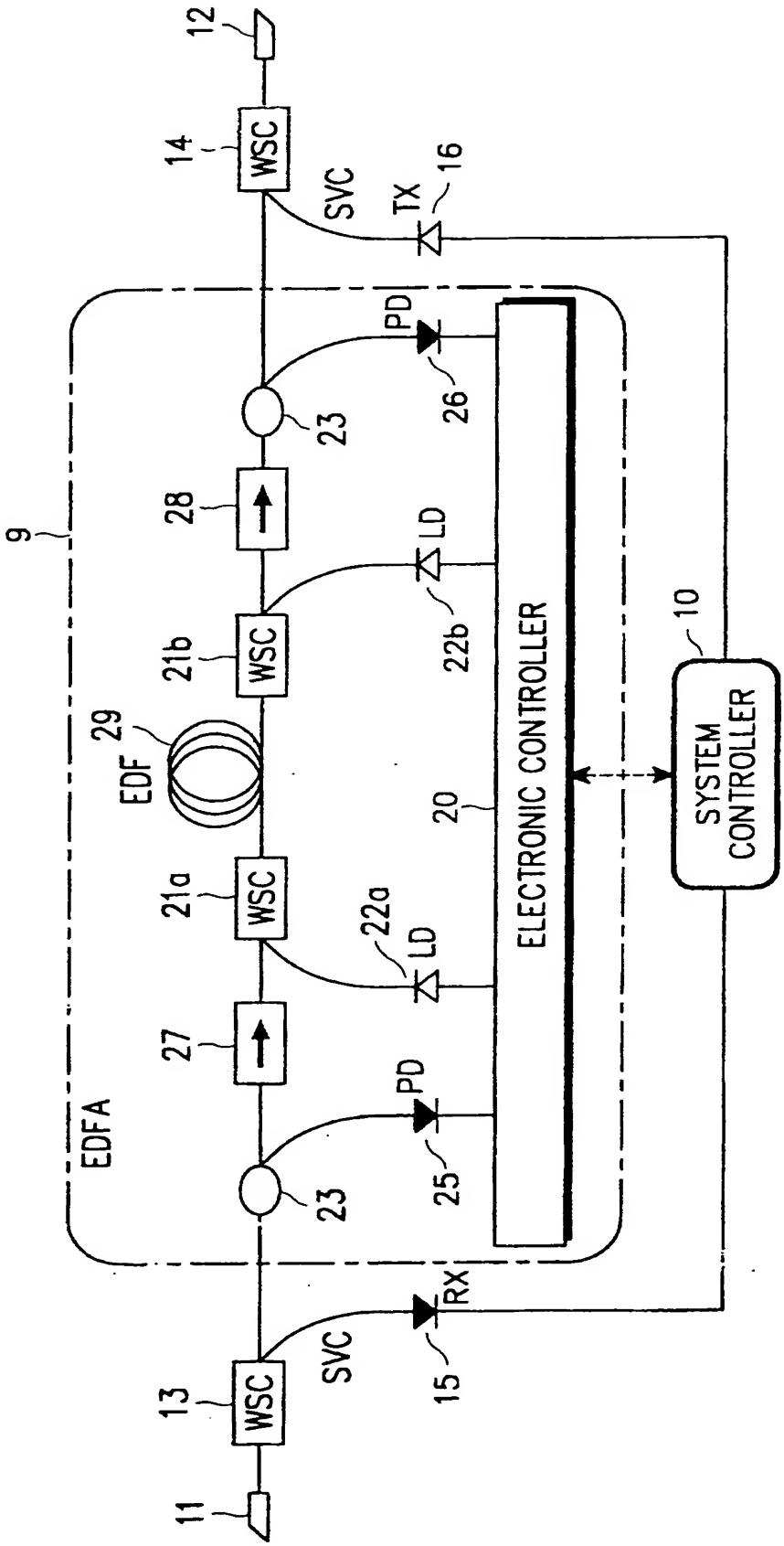
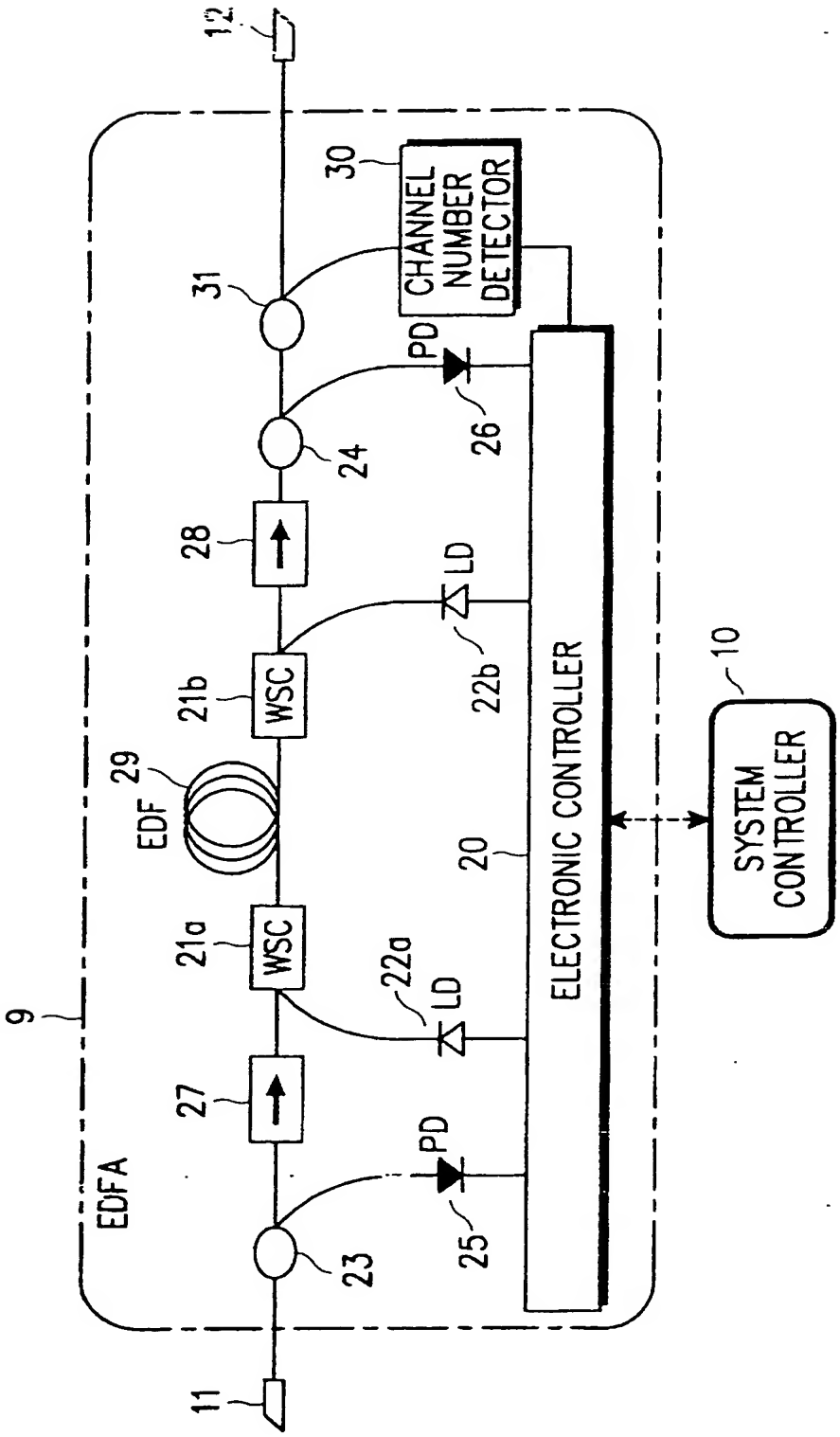


FIG. 2



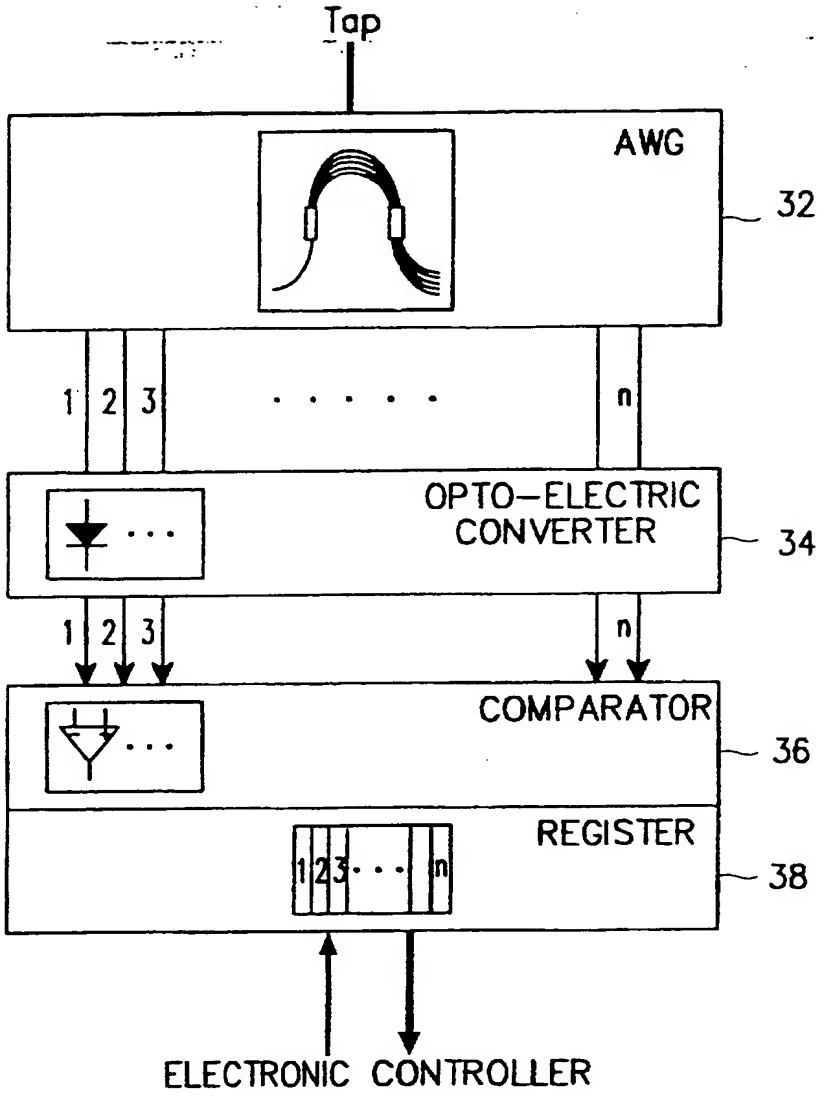


FIG. 3

OUTPUT POWER STABILIZATION OF WDM OPTICAL FIBRE AMPLIFIER

BACKGROUND TO THE INVENTION

The present invention relates generally to stabilisation of the output power of an optical fibre amplifier applied to an optical relay in a WDM (Wavelength Division Multiplex) optical transmission system, and in particular, to an apparatus and method for stabilising the output power of an optical fibre amplifier according to the number of channels of an input optical signal.

An optical fibre amplifier in an optical transmission system is simple in structure and economical since it amplifies an optical signal directly without opto-electric conversion.

Fibre Optic amplification occurs through the stimulated emission of an active optical fibre doped with a rare-earth element such as erbium (Er [68]), praseodymium (Pr [59]), or ytterbium (Yb [70]).

A WDM scheme widely employed in the current optical transmission system uses a 1550nm wavelength band (about 1530-1560nm) as a signal band. Hence an EDFA (Erbium-Doped Fibre Amplifier) is usually used due to its nature appropriate for amplification of an optical signal in the 1550nm band. The EDFA amplifies a optical transmission signal generally in an optical relay.

FIG. 1 is a block diagram of an EDFA and devices related for stabilising the output power of the EDFA according to the number of channels in a conventional optical delay being a kind of WDM optical transmission system. referring to FIG. 1, a wavelength selective coupler (SC) 13 at

an input side separates an optical signal received through an input terminal 11 into data channels and a supervisory channel (SVC). In general, a data channel transmits user data and an SVC transmits information about system operation.

The EDFA 9 amplifies the optical signal of the data channel received from the WSC 13 and feeds the amplified data channel signal to a WSC 14 at an output side. An optical receiver (RX) 15 converts the optical signal of the SVC received from the WSC 13 to an electrical signal and feed the electrical signal to a system controller 10 of the optical relay. The system controller 10 provides control signals to function blocks (not shown) as well as the EDFA 9 based on the SVC information and controls the whole operation of the optical relay. In addition, the system controller 10 outputs the SVC information to an optical transmitter (TX) 16. The optical transmitter 16 converts the SVC information to an optical signal and the WSC 14 couples the optical signal with the data channel optical signal amplified in the EDFA 9. The coupled signal is transmitted to an output terminal 12.

Meanwhile, the EDFA 9 of FIG. 1 uses a bi-directional pumping scheme and thus has first and second LDs (Laser Diodes) 22a and 22b for generating forward and reverse pumping light, respectively. First and second WSCs 21a and 21b couple the optical signal with the pump light received from the first and second LDs 22a and 22b and feeds the coupled signal to an EDF 29.

The EDF 29 receives the optical signal of the data channel separated by the WSC 13 through an optical divider 23 at the input side, an optical isolator 27 at the input side, and the first WSC 21a and amplifies the data chan-

nel signal. Then, the amplified optical signal is output through the second WSC 21b, an optical isolator 28 at the output side, and an optical divider 24 at the output side. The optical dividers 23 and 24 divide a predetermined amount (e.g., 1/100) of the input and output optical signals of the EDFA 9 and output the divided optical signals to photo-diodes (PDs) 25 and 26 at the input and output sides, respectively in order to detect the intensities of the input and output optical signals of the EDFA 9.

The PDs 25 and 26 convert the received input and output optical signals to electrical signals and provide the electrical signals to an electronic controller 20. Then, the electronic controller 20 measures the intensities of the input and output optical signals and controls the outputs of the first and second LDs 22a and 22b to stabilise the intensity of an output optical signal at a predetermined target level.

The target intensity level varies with the number of channels. That is, the light intensity of each channel in the output signal of the EDFA 9 is stabilised at a predetermined level and thus the target output power of the EDFA 9 increases with the number of channels. For example, the target output power is twice higher for transmission of 16 channels than for transmission of 8 channels so that the light intensity of each channel is maintained at the same level in both 16- and 8-channel transmissions.

The WDM transmission scheme frequently experiences a variation in the number of channels due to reconfiguration or combination of networks, or add/drop of channels. Information about the number of channels is detected by

the system controller 10 via the SVC and fed to the electronic controller 20 of the EDFA 9. Then, the electronic controller 20 sets a target output power level according to the number of the current transmission channels.

However, the electronic controller 20 of the EDFA 9 cannot adapt itself immediately to a change in the number of data channels in some cases. This is because the information about the number of the data channels is loaded on an SVC, the SVC is analysed by the system controller 10 through the WSC 13 and the optical receiver 15, and then fed to the electronic controller 20 of the EDFA 9. For example, if a 16-channel transmitting WDM system transmits 8 channels, the intensity of an 8-channel optical signal is instantaneously dropped while the EDFA 9 is controlling its output power to a target level corresponding to 16-channel transmission, and then the EDFA 9 increases the amplification rate of the input optical signal to make its output power constant. As a result, the intensity of each channel in the optical signal increases abruptly.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide an apparatus and method for adaptively stabilising the output of a WDM optical fibre amplifier instantly at a change in the number of channels.

Accordingly, the present invention provides a method of stabilising the output power of a WDM optical fibre amplifier according to the number of data channels, comprising:

extracting part of an optical signal of the optical fibre amplifier;

WDM-demultiplexing the extracted light into light in the wavelength bands of data channels;

detecting the number of channels in use from the light present in each wavelength band; and

controlling the intensity of the output optical signal according to the number of channels detected.

Preferably, the number of channels is detected by:

converting light in each wavelength band to an electrical signal;

comparing each of the electrical signals with a respective signal at a reference level; and

determining the number of channels in use on the basis of those comparisons.

The present invention also provides an apparatus for stabilising the output power of a WDM optical fibre amplifier according to the number of data channels, comprising means for extracting part of an optical signal of the optical fibre amplifier, WDM-demultiplexing the extracted light into light in the wavelength bands of data channels, detecting the number of channels in use from the light present in each wavelength band and controlling the intensity of the output optical signal according to the number of channels detected.

Preferably, the apparatus comprises a channel number detector for WDM-demultiplexing the extracted light into light in the wavelength bands of data channels and detecting the number of channels in use from the light in each wavelength band.

The channel number detector may comprise:

a demultiplexer for WDM-demultiplexing the extracted light into light in the wavelength bands of data chan-

nels;

an opto-electric converter for converting light in each wavelength band to an electrical signal; and

a comparator for comparing each electrical signal with a respective signal at a reference level and outputting the result of the comparison to indicate the or absence of a signal in the channel occupying the corresponding wavelength band.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1 is a block diagram of an optical fibre amplifier and a portion related with optical fibre output stabilisation based on the number of channels in an optical relay of a conventional WDM optical transmission system;

FIG. 2 is a block diagram of an optical fibre amplifier and an optical fibre output stabilising apparatus based on the number of channels in an optical relay of a WDM optical transmission system according to an embodiment of the present invention; and

FIG. 3 is a block diagram of a channel number detector shown in FIG. 2.

DETAILED DESCRIPTION

FIG. 2 is a block diagram of an optical fibre amplifier and an optical fibre output stabilising apparatus based on the number of channels in an optical relay of a WDM optical transmission system according to an embodiment of the present invention. Referring to FIG. 2, the EDFA 9 of the present invention need not receive information about channel number from the system controller 10 for output power stabilisation based on the channel number.

In accordance with the present invention, a channel number detector 30 is provided in the EDFA 9 for detecting information about the number of channels and providing the information to the electronic controller 20. Since the present invention does not analyse an SVC for detection of the channel number information as compared to the prior art, FIG. 2 shows no SVC separation configuration. But, the channel number detector 30 can be added to the conventional SVC information analysing system shown in FIG. 1 in the present invention. The purpose of the channel number detector 30 is to detect the number of channel in the EDFA 9 itself to thereby reduce the time required for detection of the channel number and cope instantly with a change in the channel number in an output stabilisation operation.

In the prior art, the electronic controller 20 of the EDFA 9 is informed of the number of channels based on information provided by the system controller 10. In case of heavy load on the system controller 10, it takes a long time to detect the channel number. On the contrary, the electronic controller 20 finds out the number of channels instantly regardless of load on the system controller 10 because the EDFA 9 itself detects the channel number in the present invention. Now there will be given a detailed description of the EDFA 9 according to the present invention.

In accordance with the embodiment of the present invention, the EDFA 9 employs a bi-directional pumping scheme, which is the same as the prior art. The EDFA 9 includes the EDF 29, the first and second LDs 22a and 22b, the first and second WSCs 21a and 21b, the optical divider 23, the PD 25, and the optical isolator 27 at an input

side, and the optical isolator 28, the optical divider 24, and the PD 26 on an output side. These function blocks operate in the same manner as their counterparts in the prior art.

The EDF 29 receives an optical signal of a data channel through the optical divider 23, the optical isolator 27, and the first WSC 21a and amplifies the data channel signal. Then, the amplified optical signal is output through the second WSC 21b, the optical isolator 28, and the optical divider 24. The optical dividers 23 and 24 divide a predetermined amount of the input and output optical signals of the EDFA 9 and output the divided optical signals to the PDs 25 and 26, respectively. The PDs 25 and 26 convert the received input and output optical signals to electrical signals and provide the electrical signals to the electronic controller 20. Then, the electronic controller 20 measures the intensities of the input and output optical signals and controls the outputs of the first and second LDs 22a and 22b to stabilise the intensity of an output optical signal at a predetermined target level.

According to the feature of the present invention, an optical divider 31 extracts a predetermined amount, for example 1/100 of the amplified optical signal received from the EDFA 9 through the optical divider 24.

The channel number detector 30 detects the number of the current transmission channels by WDM-demultiplexing the light received from the optical divider 31 and analysing the light of each data channel. The electronic controller 20 controls the intensity of an output optical signal according to the number of channels based on the channel number information received from the channel number

detector 30.

FIG. 3 is a block diagram of the channel number detector 30 shown in FIG. 2. Referring to FIG. 3, the channel number detector 30 includes a demultiplexer 32 for receiving the predetermined amount of output light extracted by the optical divider 31 and WDM-demultiplexing the light into wavelength bands of the respective data channels. The demultiplexer 32 can be an AWG (Arrayed-Waveguide Grating) or comprised of a plurality of fibre grating filters. If the number of channels to be divided is small, the plurality of fibre grating filters are used rather than the AWG, and if the channel number is large, vice versa. To detect the number of channels of the current transmission signal by analysing the optical signal, the wavelength bands of the entire channels used in the WDM system should be checked. Therefore, the demultiplexer 32 is preferably an AWG in the present invention.

An opto-electric converter 34 converts the light in each wavelength band received from the demultiplexer 32 to an electrical signal. to do so, the opto-electric converter 34 can have an array of as many as wavelength bands.

A comparator 36 compares the level of each electrical signal received from the opto-electric converter 34 with a predetermined reference level. The comparator 36 can be comprised of operation amplifiers for processing the respective electrical signals. Here, each operation amplifier receives a corresponding electrical signal through one input terminal and a signal at a predetermined reference level through the other input terminal and compares the electrical signal with the reference signal. The reference level is set appropriately enough

to allow presence or absence of a signal to be determined from an opto-electric conversion signal in each wavelength band, and the comparison result is 0 or 1.

The output value of the comparator 36 is stored in a register 38. The register 38 is a shift register for counting comparison result values of 1s. The electronic controller 20 detects the number of channels from the stored information of the register 38.

In operation, the demultiplexer 32 of the channel number detector 30 demultiplexes an optical signal received from the optical divider 31 into optical signals in the wavelength bands of the respective data channels. The opto-electric converter 34 converts each optical signal received from the demultiplexer 32 to an electrical signal and the comparator 36 compares the electrical signal received from the opto-electric converter 34 with a signal at a predetermined reference level to determine presence or absence of a signal.

That is, if the electrical signal is at or higher than the reference level, the comparator 38 determines that a signal exists. If the level of the electrical signal is less than the reference level, the comparator 38 determines that no signal exists. Thus, it can be determined whether a corresponding wavelength band is in use or not.

The result value 1 or 0 of the comparator 38, indicating the presence or absence of a signal, is counted and stored in the register. Then, the electronic controller 20 reads the information stored in the register 38, determines the number of channels based on the read information, and controls the amplification of the EDFA 9 according to the channel number.

In accordance with the present invention as described above, part of an optical signal is divided and WDM-demultiplexed into an optical signal of each data channel. The number of channels in use for the current transmission is detected by analysing the demultiplexed optical signals and the intensity of an output signal of a WDM optical fibre amplifier is controlled according to the detected channel number. The resulting instantaneous stabilisation of the output power of the optical fibre amplifier at a change in the channel number reduces time required for output stabilisation and increases transmission quality.

Especially, with use of the extra channel number detection function block, the optical fibre amplifier itself detects the number of channels in a shorter time. Consequently, time for detecting the number of channels is reduced and the output power of the optical fibre amplifier is stabilised instantaneously at a change in the channel number, as compared to the conventional technology.

While the invention has been described with reference to a preferred embodiment, it will be understood that various changes may be made. For example, the optical divider 31 and the channel number detector 30 are disposed at the output terminal of the EDFA to detect the channel number by analysis of an output optical signal in the embodiment of the present invention since an amplified optical signal is more favourable for signal division, measurement, and error reduction than a non-amplified and thus weak optical signal. But, another embodiment can be contemplated in which the optical divider 31 and the channel number detector 30 are arranged at the input

terminal of the EDFA 9.

CLAIMS

1. A method of stabilising the output power of a WDM optical fibre amplifier according to the number of data channels, comprising:

extracting part of an optical signal of the optical fibre amplifier;

WDM-demultiplexing the extracted light into light in the wavelength bands of data channels;

detecting the number of channels in use from the light present in each wavelength band; and

controlling the intensity of the output optical signal according to the number of channels detected.

2. A method according to claim 1, in which the said optical signal of the optical fibre amplifier is a signal amplified by the optical fibre amplifier.

3. A method according to claim 1 or claim 2, in which the number of channels is detected by:

converting light in each wavelength band to an electrical signal;

comparing each of the electrical signals with a respective signal at a reference level; and

determining the number of channels in use on the basis of those comparisons.

4. The method of any one of claims 1-3, in which the intensity of the output optical signal is controlled to a target value selected from a number of possible target values corresponding to different numbers of channels, the selected target value corresponding to the number of channels detected.

5. An apparatus for stabilising the output power of a

WDM optical fibre amplifier according to the number of data channels, comprising means for extracting part of an optical signal of the optical fibre amplifier, WDM-demultiplexing the extracted light into light in the wavelength bands of data channels, detecting the number of channels in use from the light present in each wavelength band and controlling the intensity of the output optical signal according to the number of channels detected.

6. Apparatus according to claim 5 comprising an optical divider for extracting the said part of the optical signal of the optical fibre amplifier.

7. Apparatus according to claim 6 in which the said optical signal of the optical fibre amplifier is the output light of the optical fibre amplifier.

8. Apparatus according to any one of claims 5-7 comprising a channel number detector for WDM-demultiplexing the extracted light into light in the wavelength bands of data channels and detecting the number of channels in use from the light in each wavelength band.

9. Apparatus according to claim 8, in which the channel number detector comprises:

a demultiplexer for WDM-demultiplexing the extracted light into light in the wavelength bands of data channels;

an opto-electric converter for converting light in each wavelength band to an electrical signal; and

a comparator for comparing each electrical signal with a respective signal at a reference level and outputting the result of the comparison to indicate the or absence of a signal in the channel occupying the corre-

sponding wavelength band.

10. Apparatus according to claim 9 further comprising:

storage means for storing the results of the comparisons; and

a controller for detecting the number of channels based on the information stored in the storage means and controlling the intensity of the output optical signal according to the number of channels detected.

11. Apparatus according to claim 10, in which the storage means is a shift register.

12. Apparatus according to any one of claims 9-11, in which the demultiplexer includes an AWG.

13. Apparatus according to any one of claims 9-12, in which the opto-electric converter includes an array of as many photo-diodes as there are wavelength bands.

14. Apparatus according to any one of claims 9-13, in which the comparator comprises as many operational amplifiers as there are electrical signals, each operational amplifier receiving a respective electrical signal through one input terminal and a signal at a reference level through the other input terminal.

15. A method of stabilising the output power of a WDM optical fibre amplifier according to the number of data channels, the method being substantially as described herein with reference to FIGs. 2 and 3 of the accompanying drawings.

16. An apparatus for stabilising the output power of a WDM optical fibre amplifier according to the number of

data channels, the apparatus being substantially as described herein with reference to FIGs. 2 and 3 of the accompanying drawings.

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Application No: GB 0015528.3 **Examiner:** Claire Williams
Claims searched: all **Date of search:** 10 October 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H1C (CBAA, CA) H4B (BK16D)

Int Cl (Ed.7): H01L (3/067, 3/13) H04B(10/17) H04J(14/00)

Other: ONLINE: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2324667 A	(NEC CORPORATION) whole document	X:1 - 6, 8 Y: 12
X	GB 2294170 A	(FUJITSU) whole document, in particular Figure 17	1 - 9, 13, 14
X	EP 0874480 A1	(NEC CORPORATION) whole document	1, 5, 8
X	EP 0865173 A1	(FUJITSU) whole document	X:1 - 9, 13, 14 Y:12

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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